J. Pure Appl. & Ind. Phys. Vol.2 (3A), 352-358 (2012)

Polarimetric Study of Bare Soil Surface by Using X- band Scatterometer

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ABSTRACT

A Polarimetric approach is used to determine the angular variation, roughness effect and moisture effect of the soil surface on copolarization ratio and discrimination ration by using a X-band Scatterometer. Measurements were conducted for bare soil surfaces under a variety of roughness and moisture at incident angles 20^0 to 70^0. The observed data for scattering coefficient of both like polarization (VV-pol and HH-pol) are used to calculate the Copolarizied ratio ($P = \frac{\sigma^o_{hh}}{\sigma^o_{vv}}$) and Polarization Discrimination Ratio($D = \frac{\sigma^o vv - \sigma^o hh}{\sigma^o vv + \sigma^o hh}$). The Discrimination Ratio found more sensitive to soil parameters than copolarization ratio.

Keywords: Polarimetric Study, Bare Soil Surface, X-band Scatterometry.

1. INTRODUCTION

Soil moisture is a key factor of our earth and atmosphere as it regulates environment, agricultural parameters, climate change, etc., in our day-to-day life. The influence of soil moisture between land surface and climate affects dynamic of the atmosphere boundary layer, which results in a direct relationship with climate (Schmugge *et al*., 1982). Another important earth's parameter is surface roughness, which plays a role in trapping water; it thus promotes infiltration and reduces downstream runoff. The roughness of the soil surface is defined in terms of parameter rms height.

One of the most promising approaches to assess the surface roughness parameter and moisture content is microwave remote sensing, because of its sensitivity to the dielectric and geometric characteristics of objects and its penetration

capability. It has potential to acquire surface information independently of the used frequency band (Ulaby *et al*., 1982, Fung, 1994, Mattia *et al*., 1997).

A lot of work has been done to retrieve the soil moisture and surface roughness with microwave data but still uncertainties exist to how to separate the roughness and moisture information as well as retrieve these parameters more accurately with single scattering coefficient. Either the developed model is very complex or needs a lot of prior information. This is the main limitation of the existing models (Ulaby *et al*., 1982, Fung 1994, Oh *et al*., 1992, Ceraldi *et al*., 2005). For this purpose, polarimetric behavior of radar waves, which tells about orientation, and shape of the targets (i.e., roughness etc) can also support significantly to develop retrieval algorithms for radar data (Ulaby *et al*. 1982, Ceraldi, 2005). Still very few reported works are available where researchers have used the polarimetric analysis for bistatic radar data to retrieve these earth's parameters. in this paper, we have made an attempt to use the bistatic configurations with polarization behavior measurements to retrieve the moisture content in soil with minimization of the roughness effect. For this purpose, a parameter based on polarization i.e., polarimetric discrimination ratio (D) and polarimetric ratio (P) have been tested for the roughness effect, incidence angle and the soil moisture for bistatic radar data. The paper deals the angular variation of copolarization ratio and discrimination ratio and its sensitivity for soil roughness and moisture condition. For this purpose, an indigenously bistatic scatterometer has been assembled at X-band, which has a capability to conduct observations of various soil fields at Horizontal-Horizontal; HH-polarization and Vertical-Vertical; VV-polarization for various incidence angles at X-band (9.5 GHz).

2. METHODOLOGY

A. Test bed

Experiments were performed over specially prepared soil plots of 2 meter X 2 meter size, with five different rms heights and moisture content. The soil texture is given in table 2.

B. Roughness measurement

A surface in the *x-y* plane whose height at a point is h(x,y) above the x-y plane can be characterized statistically by its mean height $\bar{h}$. If h(x,y) is statistically in x-y plane, it is sufficient to use h(x,y) alone to characterize the statistical properties of the surface. The Standard Deviation of surface height describes the statistical variation of random component of surface height relative to the reference surface and is given as

$$h_{rms} = (\overline{h^2} - \bar{h}^2)^{1/2} \tag{1}$$

where $\bar{h}$ is mean of all heights sampled and $\overline{h^2}$ second moment of all heights sampled (Ulaby *et al*. 1982).

The surface roughness measurement profiler carried out surface roughness measurements. Points are sampled on the surface and data was collected to made a

graphical estimation of the replica of the surface.

3. SOIL MOISTURE MEASUREMENT

The soil moisture was calculated by taking the soil samples from the eight to ten points in the sandpit. These soils were weighted and then dried at 110 degree for 10-12 hours and the weight of the dried soil is measured. The percentage of gravimetric soil moisture were calculated with equation.

$$m_g\,\% = \frac{\text{weight of moist soil} - \text{weight of dry soil}}{\text{weight of moist soil}} \times 100 \qquad (2)$$

4. MEASURMENT SETUP

Microwave bistatic measurements were taken at X-band by the indigenously assembled bistatic scatterometer as (Ulaby *et al*. 1982, Curie 1989) details are in table 1. This system was designed for measuring scattered power al X-band for two polarizations (i.e., Horizontal-Horizontal; HH- pol. and Vertical-Vertical; VV-pol) and incidence angle 20 degree to 70 degree at the interval of ten degree with the pyramidal horn antennas. The antennas were mounted on the portable stands, in which height of antenna can be varied from 50 cm to 3.0 m. The calibration of the scatterometer is done with the help of an Aluminum sheet of known radar cross section (Curie 1989).

5. SCATTERING COEFFICIENT COMPUTATION

Pyramidal horn antennas are used to take scattering coefficient of the soil plots. To calibrate the system, the power received by Aluminum sheet of known radar cross section at the receiving antenna, for different angle of incidence, was recorded with power meter. The radar cross section of the aluminum sheet was calculated by using the equation 3 (Curie, 1989) as

$$_{Al}\sigma_{pp}(\theta) = \frac{4\pi A^2}{\lambda^2}\left[\frac{\sin(kb\sin\theta)}{kb\sin\theta}\right]^2 \cos^2\theta \quad p = v \text{ or } h \qquad (3)$$

where, $_{Al}\sigma_{pp}(\theta)$ radar cross section of aluminum sheet, A is area of sheet, λ is wave length of operation, θ is angle of Incidence, b is the dimension of square sheet, and $k = \frac{2\pi}{\lambda}$.

The radar cross section of aluminum sheet can be expressed in dB as equation 4

$$_{Al}\sigma_{pp}(\theta)(dB) = 10\log_{10}\, {}_{Al}\sigma_{pp}(\theta), \quad p = v \text{ or } h \qquad (4)$$

Firstly, the observations were carried out for aluminum sheet and scattered power ($_{Al}P_{pp}$) from aluminum sheet were noted after that scattered power was observed for soil ($_sP_{pp}$) at various incidence angles and like polarization (HH- and VV-pol), and the scattering coefficient of soil ($_s\sigma^0{}_{pp}$) was computed with the help of equation 5.

$$_s\sigma^0{}_{pp}(\theta) = \frac{_sP_{pp}}{_{Al}P_{pp}} \times {}_{Al}\sigma_{pp}(\theta) \quad p = v \text{ or } h \qquad (5)$$

6. MODELING APPROACH

To make use polarization for study the effect of surface parameter (i.e.,

roughness and moisture) on scattering coefficient which is obserbed by bistatic scatterometer, we have used the polarimetric ratio (P) which is the ratio of scattering coefficients of HH- and VV-pol.(Oh et al., 1992, Dubois et al., 1995, Ceraldi et al., 2005) and given as

$$P = \frac{\sigma^o_{hh}}{\sigma^o_{vv}} \quad (6)$$

where σ^o_{hh} and σ^o_{vv} are the scattering coefficient for HH- and VV-pol respectively and obtained by equation 5. The researchers (Ceraldi *et al*. 2005, Fung 1992, Ulaby *et al*. 1982) found that it is difficult to separate the information of moisture and roughness with P and therefore, Singh et al 2003 proposed a polarimetric discrimination ratio as equation 7 (Singh *et al*. 2003) for discriminating the roughness and dielectric properties of the target,

$$D = \frac{\sigma^o vv - \sigma^o hh}{\sigma^o vv + \sigma^o hh} \quad (7)$$

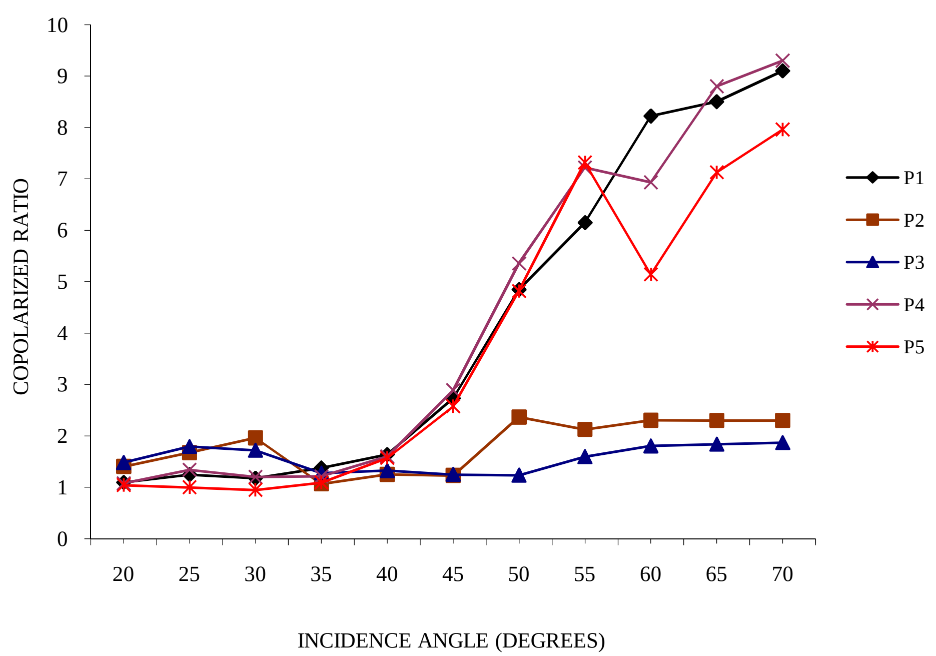

FIG . 1: Angular variation of copolarized ratio for scatt. Coff.

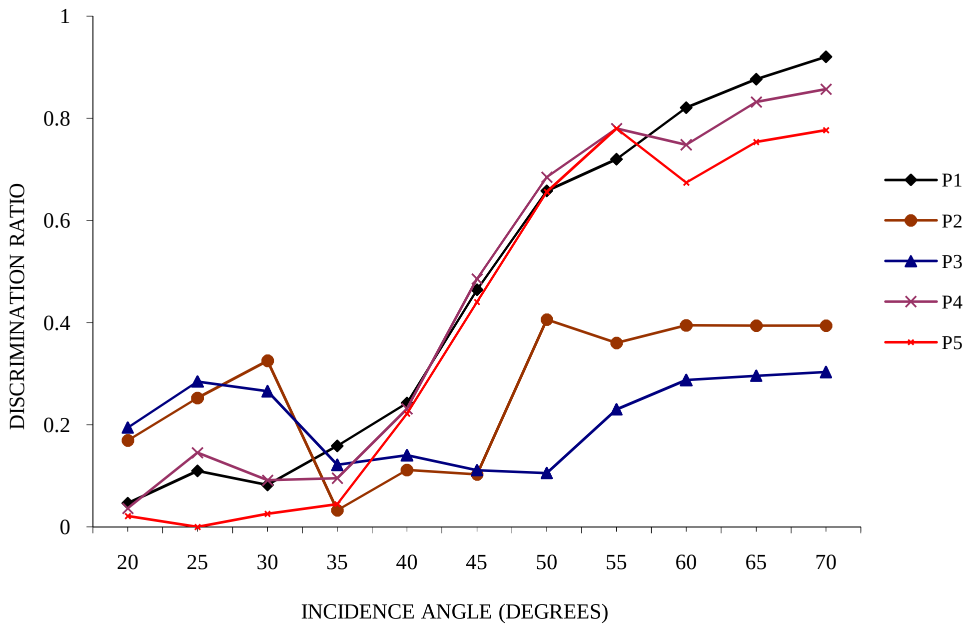

FIG.2 Angular variation of discrimination ratio for scatt.coeff.

TABLE -I
SCATTEROMETER CHARACTERISTICS

Central frequency	9.5 GHz
Frequency Band Width	0.8 Hz
Antenna Type	Dual Polarized Pyramidal Horn
Antenna band Width	8.5 Degree
Antenna Gain	20Db
Plate form Height	03 m
Cross – Poll Isolation	40dB
Calibration Accuracy	1dB

TABLE –II
SOIL TEXTURE

Percentage of Gravels	7.874
Percentage of Coarse Sand	62.27
Percentage of Silt	23.03
Percentage of Clay	6.663

7. RESULT AND DISCUSSION

A. Angular Variation of Co-polarized Ratio (P)

The observed data for scattering coefficient of both like polarization (VV-pol and HH-pol) were used to calculate the co-polarized ratio. Figure 1shows the angular variation of co-polarized ratio for five different plots (P1 to P5). The effect of incidence angle on co-polarized ratio is clearly evident. Co-polarized ratio has all most constant up to 40^0incidence angle for all surfaces and moisture but after that increasing trend is observed. The sharp increment observed for high roughness and moisture contents (i.e. plot P3, P4, and P5). This indicates that the higher incidence angles (i.e., greater than 40 degree) are more sensitive with P for higher roughness and moisture content at X- band for bistatic case.

B. Angular Variation of Polarimetric Discrimination Ratio (D)

Discrimination ratio was initially used by Singh, et al (2003, 2006) to retrieve the crop parameters at X-band and minimize the roughness effect. "D" was computed by the equation (7) for different incidence angle and different plots at X-band and shown in the figure 2. It is observed that the D is approximately constant till 40^0 incidence angle for all plots and it is very similar to the results obtained by P (figure 1). But after 40^0 incidence angle, D increases as the incidence angle and the increment is quite evident at lower roughness and moisture (i.e., P1 and P2), where as the P has not significant increment for lower roughness and moisture (i.e., P1 and P2, figure 3.2). It can be inferred that the dynamicity of D is more for lower to higher roughness and moisture content where as P has significant dynamicity on higher values of roughness and moisture.

ACKNOWLEDGEMENT

Author thanks for the financial support provided by U GC for this work.

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